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ABSTRACT

An experimental program for secondary school science students, Computer Supplemented Instruction in Science (CSI Science), was proposed to provide terminal time for all students, provide problem-solving and simulation experience, and identify those students who would most benefit from a computer-based science course. Results indicated students gravitated toward the computer for a variety of reasons. A one-classification multivariate analysis of variance followed by a two-group multiple discriminant analysis yielded a group membership identification function suitable for prescription of computer/non-computer science offerings. It was concluded that student-types could be identified and classified for CSI or non-CSI assignments. Several suggestions for implementation and identification of students to direct into CSI Science courses are presented. (Author/JM)

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COMPUTER SUPPLEMENTED INSTRUCTION IN SECONDARY SCHOOL SCIENCE: IMPLEMENTATION PROCEEDINGS AND SURVEY FINDINGS FROM A ONE-YEAR PROGRAM

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Abstract

Under the assumptions that (1) the typical secondary school curriculum in science ignores contemporary high-speed computational devices, (2) science offerings traditionally present conceptual information founded on quantitative rationale amenable to "programming", and (3) that teachers and students could rapidly assimilate the fundamentals of the computer language BASIC, an experimental program for students of Physics, Chemistry, Biology, and Earth Science was proposed. The program was labeled Computer Supplemented Instruction in Science--CSI Science.

Objectives of the program included:

1. provide on-line terminal time for all students;
2. provide both "problem-solving" and "simulation" experiences;
3. identify those for whom prescription of a "computer-based" science course would be both profitable and enjoyable.

Results obtained from a survey-type collection of data indicated that certain students gravitate toward use of the computer for a variety of reasons. Among those reasons cited by students were interesting, solve problems faster, and helps me understand what is going on. A one-classification multivariate analysis of variance followed by a two-group multiple discriminant analysis yielded a group membership identification function suitable for prescription of computer/non-computer science offerings. Analyses of those correctly and incorrectly classified yielded additional prescriptive indices. It was concluded that student-types could be identified and that these types could be classified in terms

of prescribing CSI/not-CSI assignments. Several suggestions for implementation and identification of those students to direct into CSI Science courses are presented.

COMPUTER SUPPLEMENTED INSTRUCTION IN SECONDARY SCHOOL SCIENCE: IMPLEMENTATION PROCEEDINGS AND SURVEY FINDINGS FROM A ONE-YEAR PROGRAM

> Individualization [of instruction] is not a method. It is a way to manage a classroom so that each child has his share of the teacher. Teaching is a human act. It fades when it is dehumanized. Children whose individual differences are truly met will be better taught--because of these differences and not in spite of them. (Veatch, 1970)

That each of us has been and/or will in some way be in contact with high speed computational facilities--in some capacity--is almost certanity. The nature of our profession insures that each of us will define--eventually--needs which prompt us to acquire some level of proficiency relative to use of the electronic computer. These needs may arise from areas such as recordkeeping, statistical analysis, accounting, similation of physical systems for research, etc. It is proposed herein that one of the compelling reasons for the science educator to acquire this proficiency should be, simply, for the express purpose of preparing teachers, so that these persons would then be able to effectively implement the electronic computer as another learning aid in the classroom. One might question the above, stating--alternatively--that he would have to be "shown" that implementation would produce measurable, valued increments over some evaluation criteria. It is to this issue that the body of this paper is devoted.

Before going further, be well aware of the characteristics of the Computer Supplemented Instruction in Science (CSI Science) program, not all of which are attractive. We are talking about placing a computer

terminal in the science classroom, and explicitly directing students to perform certain activities, experiences which if well conceived will result in the attainment of at least two memorable and educationally desired outcomes: (1) the student will better understand the process(es) which underlies the activity, and (2) the student will acquire an enthusiasm for dealing with the quantitative aspects of the sciences. Unfortunately, there are several undesirable features one must acknowledge as being a part of working with a teletype terminal: (1) the terminal refuses to operate; (2) the student cannot "make connections" with the terminal; (3) the telephone line is disconnected; (4) student usage exceeds the constraints spelled out in the budget. Only the latter is cataclysmic; in most of the problems one can reach a tolerable resolution given instructor expertise and perserverence. However, each of the above issues should be viewed as a deterrent to the likelihood of reaching desired outcomes. Clearly, program success as measured in terms of stated outcomes, behaviorally, is a function of teacher preparation, the teacher's drive to maintain an individualized program, and the willingness of the local school district to adequately support the program. Problems do arise and the teacher must be able, technically and pedagogically, to surmount them. As will be shown in a later section of this paper, the poorly trained, unenthused teacher will make a travesty of computer supplemented instruction, not unlike numerous program failures science educators have witnessed in the past.

Not all computer-based programs utilize the system identically. In the following section a distinction is drawn between each of three common

forms of usage. The reader is advised to differentiate between the three; especial attention should be given to the third method for using the computer as a teaching-learning aid in an individualized instruction setting.

Three Schema for Use of the Computer

Most of you are familiar with the three designs to be discussed: (1) computer-managed instruction (CMI); (2) computer-assisted instruction (CAI); (3) computer-supplemented instruction (CSI). In each instance a prior decision to individualize instruction--more or less--has been made. Cooley and Glaser (1969), in the so-called Individually Prescribed Instruction (IPI)[a] a context, clearly define the difference between CMI (management) and CAI (assistance).

> The computer can service classroom terminals which assist the teacher in assessing the student's capabilities and prescribing a course of instruction.... On the other hand, when the computer is used by the student as a means of instruction, the term commonly used is "computer-assisted instruction."

More detail on management techniques is readily available in Brudner (1968). Many sources relative to CAI exist; to list but a few, Fergerson (1970), Darnowski (1968), and Suppes (1966). However, we must differentiate between CAI and CSI, where the former might incorporate "drill and practice" (DAP), the latter "problem-solving" (PS). The distinction we wish to make is as follows: CAI can be typified by: student sits in front of a cathode-ray tube (CRT) and responds to DAP sequences; CSI is typified by: student must write a computer routine--usually a simple program--that when run on the system, will provide a solution, correctness

being a function of how well the student understood the problem and how well he translated his understanding into action. The contrast, again, is between DAP and PS. It is important to note that each scheme--CMI, CAI and CSI--embodies elements of individualization, but that the degree of and type of student involvement is quite dissimilar.

Although in direct opposition to Veatch (1970) and others cited therein, we propose that individualization is more than a philosophy, more than a pedagogical commitment. Individualization of instruction is both a way of thinking about teaching and the appropriate methodological techniques to make individualization possible. That is to say, one may well decide to individualize, but in the absence of the appropriate techniques known to individualize, concretely, little promise for an individualized offering can be anticipated. Once one commits himself to the individualized approach to instruction, then, armed with the necessary tools, he can begin to individualize his offerings, and only then. One such tool is the problem-solving approach as is the theme of CSI Science, where the student writes a computer routine which when run on a system will satisfactorily solve a problem. It is the author's contention that through CSI problem-solving certain students acquire a greater understanding of the principles and processes of science than would be expected in the absence of the PS/CSI approach. A complete sequence of high school mathematics is predicated by this maxim.[b]

Further, it was supposed that these "certain" students could be identified, and that, in fact, partitioning of the students prior to the

course in science could be undertaken, the net effect being to prescribe a computer-based course for some, a "regular" course for others, always subject to review and the student's predilection. Currently, there are several computer-based instructional projects in operation. In the following the reader is directed toward four examples of computer usage in unique instructional settings, but is also cautioned that the presentation is not intended to be exhaustive of either programs or approaches.

Four Computer-Based Projects

1. Individually Prescribed Instruction (IPI): already mentioned, IPI incorporates both CMI/CAI implementations.

2. Program for Learning in Accordance with Needs (Project PLAN): uses CMI to a great extent. PLAN, as witnessed on several occasions by the author, would appear to be one of the most productive learning programs in existence, certainly as far as this writer is concerned. The degree of self-management evidenced by PLAN students is truly remarkable. See John C. Flanagan, Individualizing Education, Palo Alto: American Institutes for Research.

3. Laboratory Program for Computer-Assisted Learning (Project LOCAL): a problem-solving venture. See Hulme, Louie L. (ed.), "Massachusetts Schools Cooperate in Computer Use," Educational Media. Vol. 1, No. 10, pp. 8-10, March 1970.

4. Huntington Computer Project (Huntington Two): simulation. See Braun, Ludwig. Huntington Two Newsletter. Brooklyn: Polytechnic Institute of Brooklyn, Vol. 2, No. 2, January 1972.[c]

More or less, these four undertakings, collectively, contain the essence of computer-based courses-of-study. The present study would most closely parallel the intent of LOCAL, where problem-solving is the primary objective; simulation of the more complex processes was a feature also employed: students "interact" on-line with a "computer-library" routine. In the following sections the CSI Science Project implementation and survey results are discussed.

The Titusville Project--Implementation

Each student who completes the usual high school sequence should have had some actual exposure to and "time-on" an on-line computer terminal. And, in the usual sequences of science offerings, each student should have had the option of attending a section of the course where use of the computer terminal was a "regular" occurrence. These are the two major objectives of CSI Science. Other objectives include (1) increased understanding and retention of significant scientific concepts, (2) increased computational skills, and (3) greater appreciation for and involvement with applications in advanced-topics areas. These objectives were the framework used to structure an experimental program for a Pennsylvania high school located in Titusville, a town not unlike many others in the state, the most frequently identified historical attraction being the park and museum area designated as a memorial to the early Drake discoveries. Without reservation, however there did exist one highly atypical feature in the setting. The educational philosophy practiced by the local superintendent was such that an experimental program

of the type proposed would have full administrative support, backing in terms of finance and methodology. As you are--I am certain--well aware, this represents the antithesis of the commonplace. But this seemingly optimal environ was not without its shortcomings, a few of which are identified in a later section of this paper. To summarize the superintendent's attitude toward the use of computers:

> The biggest impediment to computer courses in schools is that most of today's elementary and secondary teachers were trained before data-processing and, therefore, they lack an appreciation of the computer possibilities in basic education. It is my belief that no teacher should be trained without a basic course in data-processing. Higher education could alleviate this by holding more mini courses for teachers on the possibilities of the computer.... The impact of the computer has been felt in business, research and technology, and we in education cannot ignore it much longer.[d]

All too often the dedication locally to an experimental program--commitment such as was received for CSI Science at Titusville--is lacking, a serious implementation defect and one easily capable of minimizing program effectiveness. Attempts at implementation, where local commitment is either absent or of low-level intensity, are not likely to result in any meaningful changes in the educational program. The typical practice is that when the funding runs out, the program ceases.

Once all parties had decided to participate, the program--including teacher training and computer involvement--was outlined. Essentials with respect to securing computing services were resolved in the spring of 1970. Those teachers who were to be prepared to lead CSI Science courses were selected and later attended a three-week workshop at University Park in the summer of 1970. During the short time allotted for training, teachers who had never written a computer program were expected to (1)

master the interactive computer language extended BASIC, (2) become proficient in writing generalized routines, and (3) prepare as many course-specific routines for fall implementation as time permitted. The undertaking was far too ambitious. A minimum of six weeks is needed to give these persons enough time to (1) become interested (the superintendent used appreciable coercion, a situation that is unfavorable in terms of initial program receptiveness), (2) become flexibly proficient with the system, and (3) generate a suitable portfolio of introductory-type computer applications. It would appear reasonable to state that the typical non-user trainee must undergo a period of transition, one in which appreciation for what the computer can offer and mastery of how to capitalize on its potential become well developed. This interval varies directly with initial program receptiveness. Thus--where possible--initiative for adopting CSI Science should rest with the teacher, not with (first) the administration. The reluctant trainee will require a much longer period to effect transition than will the enthusiastic teacher, one who has made the pedagogical commitment requisite to individualization as evidenced in CSI Science.

Nevertheless, at the conclusion of the workshop, all teachers were able to write computer programs and, more-or-less, had completed the introductory programs needed for use in the first weeks of classes. What was missing was the total commitment to CSI Science hoped for by the author. Since the computer system had already been secured and the ever-present administrative factor was operating, there was little doubt that the program would in fact be implemented in the school in the areas of

Earth Science, Biology, Chemistry, and Physics. Had the two driving forces identified above been absent, there would have been ample cause for alarm; at least one of the teachers had made no commitment to the program and probably would have ignored it totally if given his choice. Drive to implement was found to be related to several factors: original interest, discipline responsible for, quantitative orientation, individualization flexibility, and others. At this time it became obvious that confounding of inference would occur due to a systematic association between grade, discipline and teacher; i.e., the impact of the program would appear to be a function of, say, discipline, when in fact the real difference should be attributed to teachers. Further comment on this problem is presented in the next section, where analyses of the survey data are discussed.

Summer Workshop proceedings ranged from the usual structured sequence of content in the BASIC course[e], to an individualized, unstructured, and informal series of meetings. These meetings were held at the convenience of staff[f], given times requested by participants. Inevitable conflicts arose, problems usually associated with staff being unable--due to the fact that their normal "load" was in effect--to schedule suitable, mutually agreeable times for meeting. Several of the participants were unable to operate with any appreciable skill in the absence of their respective mentors. Again, the time allotted during which the participant was expected to attain functional maturation was too short. Further, however, one premise used as a guideline for workshop proceedings was: a segment of CSI Science material developed by the teacher for his class was worth

more than any other single piece of commercially prepared material. That is, it was supposed that teachers would become more involved with CSI Science if they created their own instructional materials. At this time we are even more devoted to this principle, but we now realize that it is only following the transition period that "spontaneous" insight into the best utilization of the computer terminal is of any likelihood. As a matter of fact, the likelihood of worthwhile utilization before or during the transition period is minuscule. A longer period for tran-ition is mandated.

Participating teachers were instructed to use their prepared materials in a sequence similar to their development, from simple, introductory activities--useful primarily to acquaint the user with computing--to more involved content-specific applications. In this domain were numerous "library" routines, mostly of a simulation nature quite like that described by Wing (1968) and Baker and Martin (1965). Numerous examples of such first-level sequences can be found: Kelsey (1967), Harvey (1968), Schwarz, Kromhout and Edwards (1969), and Showalter (1970). The literature for each of the sciences contains many references to specific computer routines; e.g., Haglund, Moss and Flynn (1966), Brown and Willis (1967), Gordus and Hanson (1965), Mann, Zeitlin and Delfino (1967), Richards (1966).

By September 1970 teachers of Physics, Chemistry, Biology, and Earth Science (Grade Eight) were prepared to implement their respective CSI Science courses. During the ensuing academic term students enrolled in CSI Science courses were taught the rudiments of BASIC and were introduced to content-specific computer applications. Many of the students

concurrent to their science course(s) were involved with computer applications in their mathematics course(s). Implementation, in general, was difficult. Titusville operates on a local telephone service; interfacing from the local system to the wide-area system proved especially troublesome. More bothersome was the experienced unreliability of the vendor with whom the school contracted for time-sharing services. The net effect of the earlier-mentioned teacher education problem, the telephone interface problems and the vendor unreliability was to prove extremely detrimental to the CSI Science program. Operating under what could only be called adverse conditions, student reaction to the program was--in many instances--more a reflection of their frustrations with the system rather than their thoughts about the program. In light of these circumstances, the findings reported in the concluding section seem remarkable indeed.

The Titusville Project--Survey Findings

In May 1971 Titusville CSI Science participants--teachers and students--were asked to complete survey forms. Students were given a form on which they recorded their thoughts. Teachers were given a second form to be completed by them and then be attached to the student's form. Finally, the attached forms were forwarded to the central office. Trained recorders in the office used the students' personal records to complete the survey forms. In December 1971 graduates in the spring of 1971 were contacted by Titusville administrators and were requested to complete a follow-up survey form. The findings in the following are based on the data collected with these forms.

What was the student reaction to the CSI Science Program? Two types of items were used in the student-completed survey form: (1) yes/no-type alternatives and (2) open-end questions or statements structured to elicit narrative responses. Consider this response as given by a senior enrolled in Physics:

> Through programming I have learned many procedures which would be difficult to learn by studying ... I have been able to use them more accurately. The availability of a computer is a valuable learning device for any math or science course.

As a college freshman this person had a positive opinion of CSI Science worth in retrospect:

> For me, there was a definite advantage in using the computer. In order to 'teach' the computer to perform a certain manipulation it was necessary that I gain a workable knowledge of the processes included. I found that as I built and elaborated upon my programs I greatly increased my own knowledge and understanding of the problems included. I find that, even now, I understand the concepts I used while working with the computer much better than the ones I learned by doing the home work problems assigned involving them.

In response to "Does our CSI Science Program help persons understand the process(es) of science better than they would have had no terminal been available? Is some valuable learning the direct result of using the computer as in CSI Science?" this graduate replied:

"I can most definitely answer yes to both the above questions."

You might ask, why one student, why only anecdotal information? The reason for this preliminary is to identify a "user" for whom, obviously, the CSI Science program (Physics) was worthwhile, valued in a self-realization sense. Equally obvious is the fact that there were many students who would not have offered so stirring a testimonial!! Our interest,

however, rests with identification of students similar to our example. We are interested in identifying some characteristics of persons like our subject, identifiers to be used in prescribing a CSI Science course for persons prior to their enrollment. Conversely, these identifiers may be used to deter student-types known to experience "program" frustration when in a CSI Science context. Let us evaluate the 1971 graduate further; below are some items from the survey instruments and this respondent's replies.

Item: How many complete programs have you written to date?

Reply: 20.

Item: (Students were asked to rank order twelve subject areas, a "1" being their favorite, a "12" the least attractive.)

Reply:

Science	4
Mathematics	2
Computer Science	1
Science-Math-Computer Science	3

Item: If you had to choose between two sections of the same subject, say, your science course for next year--one in which the computer was used regularly (both "on your own" and for specific classwork), and one where the computer was never used--which class would you choose?

Reply: Regular use.

The teacher classified this student as being dominent, self-directed, approaching learning capacity, "science-prone," expected to continue in science, and capable of high achievement in science. Ratings were obtained on 5-1 scales. This student received fives on each of the six scales. An eleventh grade I.Q. (Otis-Lennon M.A) was 122. Kuder Preference %iles: 93 mechanical; 28 computational; 83 scientific; 16 persuasive; 83 artistic;

47 literary; 25 musical; 6 social service; 68 clerical. The DAT numerical ability %ile was 60. SAT twelfth grade scores were 550 math, 590 verbal. Science and mathematics cumulatives, respectively, were B+, B.

The data used for these analyses are readily available in most schools for students Grade 10 or above. Analysis of these data is, therefore, of singular relevance, in that prescription based on these characteristics certainly is feasible. How plausible such an undertaking is is another question, one for which additional findings across the student population at Titusville must be examined. Eighth grade (Earth Science) students had not been tested with the Kuder Preference necessitating twofold analyses--with and without 8th graders.

Preliminaries to multivariate analyses.--Data analyzed were of two sets: set one included seventeen variables over an N = 355; set two included twenty-nine variables over an N = 205. The reason for dual analyses was because Grade Eight students had not been tested on the Kuder Preference, had no numerical ability scores, and had no science and mathematics scores. Also, those interested only in classifying "high school" types would, perhaps, need a separate function. A summary of the variables analyzed is presented in Table 1. The first seventeen variables are common to both phases, the last twelve are unique to phase two analyses (N = 205, NVAR = 29). Intercorrelations are shown in Tables 3 and 4.

Under the assumption that student response--in terms of continuing in CSI Science--would be a good proxy for program "success," another piece of information was requested of the student (see p.13 where the actual question posed is shown). Ideally, it might be assumed that all students

want to continue, but, rationally, students were expected to react candidly to this question. This assumption of self-partitioning with respect to further use of the computer was the foundation upon which identification of student types rested. The main emphasis of the project was to create a situation in which individual preferences would emerge; had a heavy preponderance of the students indicated "regular use" for their next science course, no partitioning and subsequent analysis could have been justified.

From Table 1 the attributes of a typical student-user can be examined. Advanced education is anticipated, so much that in fact it would seem quite likely that the question itself elicited spuriously high opinions. Science was ranked as a favorite subject, not surprising since the ranking was consummated within a science environ. Across the N = 355, mathematics ranked ahead of the other four reported selections: English, industrial arts, non-science, and science-mathematics (industrial arts was last when ranked in N = 205, the balance of the options being preserved). Clearly, although science and mathematics--separately--rank among the leaders, the combination science-mathematics is not a favorite; i.e., liking either does not insure avid preoccupation with the other. Apparently, students in Grades 10-12 (1) like science more; (2) like non-science less; (3) like English less; (4) like mathematics less; (5) like science-mathematics less; and (6) like industrial arts less. Obviously, a selection factor is operating. In a later section further comment is presented on these trends, of special interest is the science-mathematics variable. Teacher ratings

TABLE 1

SUMMARY OF DATA ANALYZED, CSI SCIENCE 1970-1971

No.	Variable Acronym	Mean[a]	Standard[a] Deviation	Comment
1	ADVED	2.74/2.80	0.44/0.41	1 = HS; 2 = college; 3 = post graduate
2	SCI	4.23/4.14	2.49/2.60	Students were asked to rank in order twelve subjects. These six were selected for analysis. See Table 2.
3	NS	6.79/6.72	2.92/3.23	
4	ENG	5.26/5.71	3.18/3.47	
5	MATH	5.12/5.44	3.37/3.39	
6	SM	7.29/7.32	2.30/2.53	
7	INDA	6.38/7.40	3.71/3.42	
8	SEX	1.46/1.47	0.50/0.50	1 = Boy; 2 = Girl
9	DOM	2.98/3.00	1.10/0.89	Teachers were asked to classify each student on each of these six scales. See Table 2.
10	DIR	3.06/3.04	1.18/1.11	
11	ALC	3.14/3.20	1.15/1.11	
12	SP	2.81/2.84	1.15/1.15	
13	ECS	2.90/2.91	1.17/1.26	
14	CHAS	2.79/2.85	1.29/1.29	
15	STABL	0.73/0.63	0.44/0.48	1 = Handles apparatus well
16	CGRADE	3.34/3.36	0.90/0.95	5 = A; 1 = F
17	I.Q.	108.86/110.55	12.43/12.93	Otis-Lennon M.A. raw score
18	MECH	45.05	26.28	Kuder Preference %iles
19	COMP	50.37	27.82	
20	SCIKP	65.44	23.49	
21	PERS	47.50	24.97	
22	ART	60.69	25.86	
23	LIT	47.11	26.23	
24	MUS	31.20	23.58	
25	SOC	54.59	26.77	
26	CLER	49.60	24.87	
27	NUMA	61.53	26.52	DAT numerical ability %ile
28	SCICOM	3.74	0.86	Average in science
29	MATCOM	3.40	0.97	Average in mathematics

[a]Read: N=355/N=205. Where N=355, the class N's were Grade 8=150, Grade 10=155, Grade 11=26, Grade 12=24.

TABLE 2

CSI SCIENCE VARIABLE IDENTIFICATION

No.	Variable Acronym	Name	No.	Variable Acronym	Name
1	ADVED	Advanced Education Plans	16	CGRADE	Average in Present Course
2	SCI[a]	Science	17	I.Q.	Otis-Lennon M.A.
3	NS[a]	Non-Science	18	MECH[c]	Mechanical
4	ENG[a]	English	19	COMP[c]	Computational
5	MATH[a]	Mathematics	20	SCIKP[c]	Scientific
6	SM[a]	Science-Mathematics	21	PERS[c]	Persuasive
7	INDA[a]	Industrial Arts	22	ART[c]	Artistic
8	SEX	Sex	23	LIT[c]	Literary
9	DOM[b]	Dominant	24	MUS[c]	Musical
10	DIR[b]	Self-Direction	25	SOC[c]	Social Service
11	ALC[b]	Approaches Learning Capacity	26	CLER[c]	Clerical
12	SP[b]	"Science Prone"	27	NUMA	Numerical Ability
13	ECS[b]	Expected to Continue in Science	28	SCICOM	Science Composite
14	CHAS[b]	Capacity for High Achievement in Science	29	MATCOM	Mathematics Composite
15	STABL	Ability to Work with Apparatus			

[a]From a set of twelve rankings. Available by written request is an identification of 84 variables collected and an intercorrelation matrix for N=205.

[b]Scaled, for example, Dominant - Retiring, 5-1. Classified by teachers.

[c]Kuder Preference scales.

are slightly above an arbitrary mid-point, and no particular trends are evident across the two groups. It is interesting to note that those in the older group were rated less able to handle apparatus without excessive problems. The lower mean value for the older group is probably a reflection of the difficulties associated with the requisite tasks. In both groups course grade and I.Q. were slightly above the values expected.

The typical student in the older group was further charaterized by above-average scores on Kuder Preference scientific, artistic and social services. Numerical ability was considerably above average. Science and mathematics composites were in the direction anticipated.

A cursory examination of the two intercorrelation tables results in identification of several "common" factors: (1) teacher-rating variables, and (2) NS-MATH-SM are of special interest. A principal components analysis of each matrix confirmed each identification. When N=355, factor one contained the six teacher-rating variables, CGRADE, and I.Q. When N=205, factor one contained the N=355 variables and NUMA, SCICOM, and MATCOM. From these findings it would appear that teachers--as a gross observation--tended to rate students much the same as they graded them. A second factor appeared in both analyses: SEX and INDA not unexpectedly were the primary elements. Factor three was of considerable interest: for N=355, NS, MATH and SM; for N=205, NS, MATH, SM and COMP. Later it is shown that from factors one and three an acceptable classification scheme can be developed. Principal components analyses were conducted as described by Finn (1968) and Bock and Haggard in Whilta (1968), Chap-

TABLE 3

INTERCORRELATIONS[a] AMONG THE VARIABLES USED FOR ANALYSIS WHEN N = 355.

	Variable	ADVED	SCI	NS	ENG	MATH	SM	INDA	SEX	DOM	DIR	ALC	SP	ECS	CHAS	STABL	CGRADE	I.Q.	SELECT
1	ADVED	--																	
2	SCI	-05	--																
3	NS	04	-27	--															
4	ENG	09	-10	-07	--														
5	MATH	00	-07	-18	-19	--													
6	SM	-03	20	-24	-37	25	--												
7	INDA	19	00	03	-02	-23	-07	--											
8	SEX	05	25	-05	-17	-03	14	48	--										
9	DOM	19	-26	16	24	-06	-16	02	-14	--									
10	DIR	19	-27	10	27	-16	-17	13	-04	70	--								
11	ALC	16	-26	12	21	-15	-17	16	02	55	75	--							
12	SP	24	-33	11	26	-13	-18	07	-17	71	83	66	--						
13	ECS	27	-32	08	31	-09	-17	-01	-18	63	74	52	82	--					
14	CHAS	26	-30	04	29	-16	-18	12	-09	68	79	58	85	83	--				
15	STABL	13	-13	02	05	-02	-08	-06	-17	28	29	14	32	30	31	--			
16	CGRADE	19	-34	10	26	-10	-19	08	-03	54	68	60	67	62	65	16	--		
17	I.Q.	20	-18	03	18	-10	-12	14	-09	31	36	20	38	37	43	09	40	--	
	SELECT[b]	02	-10	23	12	-07	-22	-01	-12	21	14	09	14	15	13	25	07	05	—

[a]All intercorrelations rounded to two decimal places and reported without leading zero and decimal point.

[b]SELECT: 1 if respondent chose "regular use," 0 if "never use". SELECT is the success proxy.

TABLE 4

INTERCORRELATIONS[a] AMONG THE VARIABLES USED FOR ANALYSIS WHEN N = 205

	Variable	ADVED	SCI	NS	ENG	MATH	SM	INDA	SEX	DOM	DIR	ALC	SP	ECS	CHAS	STABL	CGRADE	IQ	MECH	COMP	SCIKP	PERS	ART	LIT	MUS	SOC	CLER	NUMA	SCICOM	MATCOM	SELECT
1	ADVED	--																													
2	SCI	-15	--																												
3	NS	-02	-29	--																											
4	ENG	08	-26	-10	--																										
5	MATH	17	-07	-25	-24	--																									
6	SM	01	29	-20	-46	33	--																								
7	INDA	08	01	11	-16	-20	-05	--																							
8	SEX	03	21	09	-24	04	22	44	--																						
9	DOM	21	-26	12	28	-07	-19	13	-02	--																					
10	DIR	22	-28	08	30	-13	-22	20	05	79	--																				
11	ALC	10	-27	11	24	-22	-19	19	08	60	82	--																			
12	SP	28	-34	08	34	-11	-22	13	-11	75	87	71	--																		
13	ECS	34	-29	04	37	-05	-20	07	-10	63	73	52	80	--																	
14	CHAS	31	-27	02	35	-12	-19	14	-06	70	80	61	86	82	--																
15	STABL	29	-16	02	11	-01	-12	08	-16	31	25	14	36	33	36	--															
16	CGRADE	23	-33	09	32	-12	-20	16	08	55	70	66	65	56	62	16	--														
17	IQ	24	-16	05	24	-10	-18	10	-06	27	28	18	30	28	34	11	32	--													
18	MECH	-19	01	06	00	-01	06	-16	10	03	-01	-07	-04	-02	-04	-16	01	06	--												
19	COMP	-07	05	07	15	-23	-24	07	-06	03	03	05	02	-02	02	07	-01	-04	-22	--											
20	SCIKP	04	-33	22	15	-04	-22	12	02	14	20	18	17	15	12	03	21	10	10	24	--										
21	PERS	-02	13	-16	-07	15	23	-17	-04	-06	-17	-12	-12	-13	-16	00	-18	00	-16	-06	-38	--									
22	ART	-03	12	-14	00	04	12	09	06	-14	-12	-12	-13	-01	-04	-13	-09	-04	11	-31	-23	-04	--								
23	LIT	09	-10	05	-15	03	03	04	-11	-07	-08	02	-02	-05	-04	02	-04	06	-31	08	-18	02	-19	--							
24	MUS	07	05	08	-11	-05	-07	03	-10	-14	-01	00	-02	-04	-01	04	-06	10	-03	03	-10	03	02	03	--						
25	SOC	14	-06	05	-12	-03	07	19	17	09	11	08	07	07	10	00	05	01	-22	-12	-04	-08	-19	06	-27	--					
26	CLER	-02	09	-09	14	-01	-13	-01	-28	01	-08	-05	-04	-09	-07	12	-09	-09	-30	45	-05	31	-20	08	-02	-29	--				
27	NUMA	20	-04	07	25	-18	-24	07	-03	22	20	16	22	22	27	23	26	56	02	20	18	-10	-05	-11	10	-04	05	--			
28	SCICOM	22	-23	11	31	-09	-24	12	01	45	47	41	48	44	50	11	59	41	-02	14	21	-24	-16	-02	02	06	-03	40	--		
29	MATCOM	33	-11	06	22	-21	-13	19	12	30	37	33	36	30	34	10	42	36	01	15	14	-14	-07	-09	03	-03	03	51	61	--	
	SELECT[b]	08	-11	22	19	-09	-28	11	-05	17	10	04	08	12	13	22	01	11	08	13	15	-19	-09	-11	06	-01	06	15	05	02	--

[a]All intercorrelations rounded to two decimal places and reported without leading zero and decimal point.

[b]SELECT: 1 if respondent chose "regular use," 0 if "never use". SELECT is the success proxy.

ter Three. And, SELECT correlates substantially with NS, SM, DOM, and STABL in both examples.

Multivariate analyses, independent variables X instructional level.--After grouping the data according to level, a one-classification multivariate analysis of variance produced the results displayed in Tables 5 and 6. All analyses of this type were completed as outlined by Finn (1968). Clearly, subject ranking trends can be observed; teachers seemed to classify their students more-or-less independent of discipline, i.e., level. STABL, again, appears to be a function of task difficulty, and I.Q. moves in the usual direction. It is interesting to note the shifts evidenced in SCIKP, PERS and CLER. The physics student was (1) much higher on SCIKP, much lower on PERS, and much higher on CLER than either of the remaining possibilities. Perhaps the most striking differences occur in NUMA and MATCOM. Self-selection, i.e., the usual course-selection options, is obvious; the same kinds of people will not be found in all levels of science instruction. Those without requisite motivation/ability will eliminate themselves. What was indicated was further classification analyses X instructional level, but insufficient sample points proved prohibitive. Therefore, the next phase of the analysis was to generate group-type classification relationships.

Multiple Discriminant Analysis and Group Membership.--The variable SELECT was of great interest, for it was from the student's choice of a next course that inference would be made; group-membership classifications would be in terms of SELECT. Of those in the larger group, 190 indicated

TABLE 5

MULTIVARIATE ANALYSIS OF VARIANCE,[a] N = 355, NVAR = 17:
INDEPENDENT VARIABLES X FROM INSTRUCTIONAL LEVELS[b]

Variable No.	Name	Group Means 1	2	3	4	Univariate F	p-Less Than
1	ADVED	2.26	2.57	2.38	2.92	4.95	0.0023
2	SCI	4.36	4.05	5.15	3.58	2.15	0.0933
3	NS	6.88	6.89	4.50	8.04	7.25	0.0001
4	ENG	4.65	5.46	5.65	7.33	5.79	0.0008
5	MATH	4.67	5.86	5.19	3.00	6.90	0.0002
6	SM	7.24	7.46	7.81	5.92	3.66	0.0128
7	INDA	5.00	7.32	7.50	7.75	13.43	0.0001
8	SEX	1.45	1.51	1.38	1.29	1.63	0.1811
9	DOM	2.95	2.99	3.12	2.96	0.18	0.9095
10	DIR	3.09	3.05	3.15	2.92	0.21	0.8924
11	ALC	3.05	3.19	3.35	3.17	0.65	0.5850
12	SP	2.77	2.86	2.77	2.75	0.20	0.8983
13	ECS	2.89	2.98	2.73	2.67	0.75	0.5204
14	CHAS	2.70	2.79	3.12	2.96	0.93	0.4276
15	STABL	0.86	0.57	0.85	0.79	12.46	0.0001
16	CGRADE	3.33	3.39	3.23	3.25	0.40	0.7562
17	IQ	106.55	108.75	113.62	118.88	8.73	0.0001

[a] $F_m = 5.54$, $p < 0.0001$ with 51 and 998.1541 degrees of freedom.

[b] $N_i = 150, 155, 26, 24$; Grade 8, Grade 10, Grade 11, Grade 12.

TABLE 6

MULTIVARIATE ANALYSIS OF VARIANCE,[a] N = 205, NVAR = 29:
INDEPENDENT VARIABLES X THREE INSTRUCTIONAL LEVELS[b]

Variable No.	Name	Group Means 1	2	3	Univariate F	p-Less Than
1	ADVED	2.57	2.38	2.92	2.62	0.0756
2	SCI	4.05	5.15	3.58	2.66	0.0721
3	NS	6.89	4.50	8.04	9.00	0.0002
4	ENG	5.46	5.65	7.33	3.09	0.0479
5	MATH	5.86	5.19	3.00	8.02	0.0005
6	SM	7.46	7.81	5.92	4.56	0.0116
7	INDA	7.32	7.50	7.75	0.18	0.8394
8	SEX	1.51	1.38	1.29	2.42	0.0912
9	DOM	2.99	3.12	2.96	0.26	0.7700
10	DIR	3.05	3.15	2.92	0.28	0.7547
11	ALC	3.19	3.35	3.17	0.24	0.7862
12	SP	2.86	2.77	2.75	0.16	0.8542
13	ECS	2.98	2.73	2.67	0.95	0.3878
14	CHAS	2.79	3.12	2.96	0.78	0.4596
15	STABL	0.57	0.85	0.79	5.18	0.0064
16	CGRADE	3.39	3.23	3.25	0.49	0.6124
17	IQ	108.75	113.62	118.88	7.68	0.0007
18	MECH	44.82	45.77	45.79	0.03	0.9754
19	COMP	49.41	41.73	65.88	5.29	0.0058
20	SCIKP	65.73	46.85	83.71	17.97	0.0001
21	PERS	47.84	57.96	33.96	6.12	0.0027
22	ART	61.23	59.19	58.83	0.14	0.8709
23	LIT	47.18	44.27	49.71	0.27	0.7646
24	MUS	29.12	31.81	44.00	4.28	0.0152
25	SOC	56.82	52.96	41.92	3.35	0.0371
26	CLER	46.96	51.85	64.21	5.34	0.0056
27	NUMA	57.32	64.92	85.04	12.96	0.0001
28	SCICOM	3.66	3.51	3.90	1.02	0.3636
29	MATCOM	3.21	3.05	3.73	2.50	0.0845

[a] $F_m = 3.75$, $p < 0.0001$ with 58 and 348.0000 degrees of freedom.

[b] $N_i = 155, 26, 24$; Grade 10, Grade 11, Grade 12.

a preference for CSI Science in the next course, 165 selected the option "never use", about 53% and 47% respectively. Of those in the smaller group, 89 (44%) and 116 (56%) were the proportions selecting the respective alternatives. The shifts--53% to 44% and 47% to 56%--probably are a manifestation of at least two operatives: (1) the self-selection process (some "users" are not science-prone), and (2) the teacher/discipline impact felt at Grades 10-12, where the press to complete work might well supersede user inclination; e.g., a terminal problem is far more acute for those requiring usage than for those passing time.

Discriminant analyses were conducted in two-stage fashion. Using the well-known "BIOMED" package (Dixon, 1968), a "step-up" analysis of each group resulted in the identification of two subsets of variables: subset 1--for N = 355--consisted of four variables (NS, SM,DOM, and STABL), subset 2 consisted of three variables (NS, SM, STABL). The purpose of stage one was to optimize "hit-miss" classifications while minimizing the number of variables used in the process. In stage two functions were again generated but including only the respective variables from stage one. The results are shown in Tables 7 and 8. In both stages blocking was in terms of the variable SELECT. Discriminant analyses and classifications followed guidelines as shown in Anderson (1958) and Overall and Klett (1972). Note that row marginals are preserved--column shifts are usually observed as variables are added. Given that the percent of hits in each example differ little and that the number of variables needed to reach these levels of mutual classification are identical except for the addition of DOM, there appears to be

TABLE 7

DISCRIMINANT ANALYSIS OF FOUR VARIABLES FOR THE LARGER GROUP, N = 355

N Groups = 2 Variables Used: NS, SM, DOM, STABL
N/Groups: Code 0 = 165; Code 1 = 190 $U_{4,1,353} = 0.85726$

Mean Vectors

Variable No.	Name	Groups Code = 0	Code = 1	Grand Means
1	NS	6.07273	7.41053	6.78873
2	SM	7.82424	6.82105	7.28732
3	DOM	2.72727	3.19474	2.97746
4	STABL	0.61212	0.83158	0.72958

Functions

Variable No.	Name	Code = 0	Code = 1
1	NS	0.96250	1.10040
2	SM	1.92896	1.78409
3	DOM	2.32406	2.54711
4	STABL	2.36509	3.41995
	Constant	-10.06336	-9.97658

Hit/Miss Classification

Group	Classified		
0	109	56	% hits = 66
1	65	125	

TABLE 8

DISCRIMINANT ANALYSIS OF THREE VARIABLES FOR THE SMALLER GROUP, N = 205

N Groups = 2 Variables Used: NS, SM, STABL
N/Group: Code 0 = 116; Code 1 = 89 $U_{3,1,203} = 0.86126$

Mean Vectors

Variable No.	Name	Groups Code = 0	Code = 1	Grand Means
1	NS	6.11207	7.51685	6.72195
2	SM	7.93965	6.51685	7.32195
3	STABL	0.54310	0.75281	0.63415

Functions

Variable No.	Name	Code = 0	Code = 1
1	NS	0.79971	0.92009
2	SM	1.53363	1.32794
3	STABL	3.08604	3.98064
	Constant	-10.06336	-9.97658

Hit/Miss Classification

Group	Classified		
0	83	33	% hits = 66
1	31	58	

little justification for classifying the smaller group separately, unless only levels 10-12 are involved (locally) in prescription of alternate course sections.

Consider the hit/miss table for N = 355, and call the cells 0,0/ 0,1/1,0/1,1. Cells 0,0 and 1,1 are hits, cells 0,1 and 1,0 are misses. Then, of the 355 samples a total of 234 were correctly classified--about 66% "success." Of greater concern are the 34% misses. Clearly, a 0,1 prescription may dislike the prescribed section but may then request transfer to a non-CSI section, but the 1,0 miss is excluded from CSI Science and has no obvious recourse, a regretable situation. In educational settings where all students may begin a CSI Science course and if dissatisfied may then transfer there is no problem, for the misses of type 1,0--those who would enjoy the experience but were inadvertently misclassified into the non-CSI group--would not be systematically excluded. Nevertheless, the purpose is to generate a model for prescription; CSI Science is an expensive innovation and high achievement in science is not, absolutely, a function of time spent in CSI activities. That is to say, unique achievements attributable directly to SCI have not been isolated. Misclassification is a real problem, one deserving of further investigation, for far better to realize some fractional "drop-out" of 0,1's than to prohibit 1,0 memberships. Additional classification information is presented later but first a note of caution.

The particular step-up multiple discriminant routine used for this evaluation is predicated by "prior" probabilities, in this instance defaulted to 0.5 each. Following computation of the functions, posterior

probabilities and Mahalanobis distances are computed for each sample; classification is then undertaken, where the sample is classified into the group whose code is associated with the greatest probability. Thus, a probability of 0.51 goes to one group, a 0.49 to the opposite classification. The smaller the D^2 value the more valid is the assumption of correct classification. Values close to the demarcation point are quite susceptable to misclassification. Farther investigation of this problem with reference to the 1,0 cell is tantamount, but beyond the scope of the present study.

Analysis of Classification Cells.--More information about the characteristics of those elements in each of the four classification cells was required for more accurate prescription. Sample points were separated physically into four groups to correspond to cells 0,0/0,1/1,0/1,1 for both N = 355 and N = 205. Tables 9-14 summarize one-classification multivariate analyses of variance for the respective N's; analyses were completed for (1) four classifications, (2) the two classifications for CODE = 0, and (3) the two classifications for CODE = 1 (1,0/1,1).

From Tables 9 and 12 it is clear that--from columns 2 and 3 of each table--a miss is much more like his column counterpart in the opposite row (from comparison of columns 1 and 2, 1 and 4). Clearly, misses are very much like hits in the opposite row over the variables observed here; looking at 0,0/0,1 for N = 355, it is evident that on each of the four variables a 0,1 is much more like a 1,1 and a 0,0 is much more like a 1,0.

At this point additional sources of variation were necessary to

TABLE 9

MULTIVARIATE ANALYSIS OF VARIANCE,[a] N = 355, NVAR = 4:
INDEPENDENT VARIABLES X FOUR CLASSIFICATIONS[b]

Variable No.	Name	Group Means[c] 1	2	3	4	Univariate F	p-Less Than
1	NS	5.14	7.89	5.23	8.54	50.16	0.0001
2	SM	8.33	6.84	8.22	6.10	28.00	0.0001
3	DOM	2.40	3.36	2.49	3.56	36.48	0.0001
4	STABL	0.45	0.93	0.58	0.96	42.83	0.0001

[a] $F_m = 42.80$, $p < 0.0001$ with 12 and 921.0127 degrees of freedom.

[b] 1 = 0,0; 2 = 0,1; 3 = 1,0; 4 = 1,1.

[c] N_i = 109, 56, 65, 125.

TABLE 10

MULTIVARIATE ANALYSIS OF VARIANCE,[a] N = 355, NVAR = 4:
INDEPENDENT VARIABLES X TWO CODE = 0 CLASSIFICATIONS[b]

Variable No.	Name	Group Means[c] 1	2	Univariate F	p-Less Than
1	NS	5.14	7.89	45.76	0.0001
2	SM	8.33	6.84	22.50	0.0001
3	DOM	2.40	3.36	40.58	0.0001
4	STABL	0.45	0.93	45.09	0.0001

[a] $F_m = 58.85$, $p < 0.0001$ with 4 and 160.0000 degrees of freedom.

[b] 1 = 0,0; 2 = 0,1.

[c] N_i = 109 56.

TABLE 11

MULTIVARIATE ANALYSIS OF VARIANCE,[a] N = 355, NVAR = 4:
INDEPENDENT VARIABLES X TWO CODE = 1 CLASSIFICATION[b]

Variable No.	Name	Group Means[c] 1	2	Univariate F	p-Less Than
1	NS	5.23	8.54	78.90	0.0001
2	SM	8.22	6.10	39.17	0.0001
3	DOM	2.49	3.56	47.97	0.0001
4	STABL	0.58	0.96	55.03	0.0001

[a] $F_m = 98.29$, $p < 0.0001$ with 4 and 185.0000 degrees of freedom.

[b] 1 = 1,0; 2 = 1,1.

[c] $N_i = 65, 125$.

TABLE 12

MULTIVARIATE ANALYSIS OF VARIANCE,[a] N = 205, NVAR = 3:
INDEPENDENT VARIABLES X FOUR CLASSIFICATIONS[b]

Variable No.	Name	Group Means[c] 1	2	3	4	Univariate F	p-Less Than
1	NS	5.23	8.33	5.35	8.67	23.24	0.0001
2	SM	8.76	5.88	8.90	5.24	51.77	0.0001
3	STABL	0.45	0.79	0.55	0.86	11.50	0.0001

[a] $F_m = 31.55$, $p < 0.0001$ with 9 and 484.4641 degrees of freedom.

[b] 1 = 0,0; 2 = 0,1; 3 = 1,0; 4 = 1,1.

[c] $N_i = 83, 33, 31, 58$.

TABLE 13

MULTIVARIATE ANALYSIS OF VARIANCE,[a] N = 205, NVAR = 3:
INDEPENDENT VARIABLES X TWO CODE = 0 CLASSIFICATIONS[b]

Variable No.	Name	Group Means[c] 1	2	Univariate F	p-Less Than
1	NS	5.23	8.33	31.56	0.0001
2	SM	8.76	5.88	62.60	0.0001
3	STABL	0.45	0.79	12.11	0.0001

[a] F_m = 54.65, $p < 0.0001$ with 3 and 112.0000 degrees of freedom.

[b] 1 = 0,0; 2 = 0,1.

[c] N_i = 83, 33.

TABLE 14

MULTIVARIATE ANALYSIS OF VARIANCE,[a] N = 205, NVAR = 3:
INDEPENDENT VARIABLES X TWO CODE = 1 CLASSIFICATIONS[b]

Variable No.	Name	Group Means[c] 1	2	Univariate F	p-Less Than
1	NS	5.35	8.67	25.39	0.0001
2	SM	8.90	5.24	62.13	0.0001
3	STABL	0.55	0.86	11.87	0.0001

[a] F_m = 54.11, $p < 0.0001$ with 3 and 85.0000 degrees of freedom.

[b] 1 = 1,0; 2 = 1,1.

[c] N_i = 31, 58.

improve prescription. Returning to the original sets of independent variables (N = 355, NVAR = 17; N = 205, NVAR = 29) another set of multivariate analysis of variance tables was compiled, one for each N and are presented in Tables 15 and 16. Of special interest was the question of

TABLE 15

MULTIVARIATE ANALYSIS OF VARIANCE,[a] N = 355, NVAR = 13[b]: INDEPENDENT VARIABLES X FOUR CLASSIFICATIONS[c]

Variable No.	Name	Group Means[d] 1	2	3	4	Univariate F	p-Less Than
1	ADVED	2.32	2.64	2.29	2.55	2.56	0.0548
2	SCI	4.94	3.67	5.11	3.41	12.10	0.0001
3	ENG	4.51	5.48	5.49	5.70	3.04	0.0291
4	MATH	5.60	4.93	5.68	4.50	2.85	0.0374
5	INDA	6.52	6.23	6.38	6.33	0.09	0.9649
6	SEX	1.54	1.50	1.55	1.33	4.92	0.0024
7	DIR	2.62	3.41	2.51	3.58	23.04	0.0001
8	ALC	2.84	3.39	2.68	3.53	12.63	0.0001
9	SP	2.39	3.13	2.29	3.31	21.89	0.0001
10	ECS	2.47	3.20	2.51	3.35	16.91	0.0001
11	CHAS	2.29	3.21	2.34	3.26	17.86	0.0001
12	CGRADE	3.07	3.68	2.98	3.62	14.57	0.0001
13	IQ	107.72	109.20	105.35	111.54	4.08	0.0072

[a] $F_m = 3.18$, $p < 0.0001$ with 39 and 1004.5991 degrees of freedom.

[b] The thirteen variables not used for classification.

[c] 1 = 0,0; 2 = 0,1; 3 = 1,0; 4 = 1,1.

[d] $N_i = 109, 56, 65, 125$.

whether or not these variables, or some linear composite thereof, might be useful with respect to improving the percent of "hits" following prescription.

Subjectively, it would appear likely that some utility can be made of the information in Tables 15 and 16. Clearly, the four groups in each example are different, and they are different across columns (classifications) such that, again, 0,0 and 1,0 appear similar as do 0,1 and 1,1. This suggests that following formal classification, prescription could be tempered with a comparison of Y's non-classification variables with the four columns shown. However, adopting this procedure would be quite speculative in that--from the principal components analyses discussed earlier--the ability of teachers to differentiate across the six scales is questionable, the typical reactions to each of the scales, CGRADE and I.Q. being related. Without further refinement, simply asking the student if he wishes to try CSI Science might be the most reliable method for deleting membership in cell 1,0.

Prescriptive Classifcation.--Under the assumptions that (1) not all students would be in CSI Science sections; (2) those shown to be classified 1,0 should be in CSI Science; and (3) those shown to be classified 0,1 should not be in CSI Science, one might choose to follow this procedure:

a. For each CSI prospect, collect the necessary information as shown in Tables 5 and 6.

b. Using the functions in Tables 7 and 8, project membership. (The larger value calculated is the indicator for final classification. See Overall and Klett (1972), Chapter Nine.)

c. For cases where either the two values are very close (say, p_0 = 0.51 and p_1 = 0.49) or there is some question as to whether the student would care to be in CSI Science, individual counseling--

TABLE 16

MULTIVARIATE ANALYSIS OF VARIANCE,[a] N = 205, NVAR = 26[b]:
INDEPENDENT VARIABLES X FOUR CLASSIFICATIONS[c]

Variable No.	Name	Group Means[d] 1	2	3	4	Univariate F	p-Less Than
1	ADVED	2.45	2.73	2.58	2.71	1.45	0.2283
2	SCI	4.87	3.21	4.65	3.34	6.22	0.0005
3	ENG	4.69	6.21	5.68	6.90	5.21	0.0018
4	MATH	5.95	5.15	6.29	4.43	3.17	0.0254
5	INDA	7.11	6.97	7.29	8.10	1.21	0.3071
6	SEX	1.52	1.42	1.48	1.41	0.60	0.6189
7	DOM	2.73	3.21	2.87	3.33	6.45	0.0004
8	DIR	2.80	3.33	2.74	3.40	5.12	0.0020
9	ALC	3.04	3.48	2.87	3.47	3.43	0.0181
10	SP	2.58	3.21	2.55	3.16	5.02	0.0023
11	ECS	2.65	3.09	2.77	3.26	3.09	0.0284
12	CHAS	2.54	3.12	2.87	3.14	3.12	0.0271
13	CGRADE	3.19	3.73	3.06	3.53	4.33	0.0056
14	IQ	108.01	112.58	108.68	114.03	3.04	0.0299
15	MECH	45.04	38.97	49.55	46.14	0.92	0.4305
16	COMP	43.95	55.73	49.35	57.03	3.10	0.0280
17	SCIKP	59.94	68.61	63.10	72.76	3.85	0.0105
18	PERS	53.65	46.67	44.39	40.83	3.34	0.0203
19	ART	64.07	59.61	68.48	52.31	3.59	0.0146
20	LIT	50.42	47.55	39.52	46.17	1.34	0.2621
21	MUS	29.54	31.09	28.10	35.31	0.90	0.4413
22	SOC	52.84	59.73	60.00	51.26	1.25	0.2932
23	CLER	46.24	53.09	47.81	53.38	1.23	0.3013
24	NUMA	53.88	68.21	60.00	69.48	5.06	0.0022
25	SCICOM	3.44	4.10	3.52	3.83	4.47	0.0046
26	MATCOM	3.05	3.67	3.10	3.37	2.46	0.0642

[a] $F_m = 1.58$, $p < 0.0002$ with 78 and 527.1438 degrees of freedom.

[b] The twenty-six variables not used for classification.

[c] 1 = 0,0; 2 = 0,1; 3 = 1,0; 4 = 1,1.

[d] $N_i = 83, 33, 31, 58$.

perhaps by using data comparable to Tables 15 and 16--is absolutely integral to "success."

d. Prescribe assignment but make it flexible, i.e., subject to review by either faculty or student. However, for one to request reassignment from CSI to non-CSI poses little other than administrative inconvenience; to go from non-CSI into CSI is another question, for an introductory period in which BASIC is absorbed and the counterpart to "teacher transition" takes place must be traversed. Merely as a suggestion, a viable resolution might be to require all students to learn BASIC and try CSI for perhaps one month, then allowing those who so desire to move back into non-CSI sections. Adhering to such a policy would insure that (1) each student would be exposed to high-speed computation, (2) have a certain--minimal--understanding of the computer, and (3) those student types who are "misses" in cell 1,0 would not be missed.

Summary

If administrative support is sanctioned, if adequate, reliable computing capability is contracted, and if teachers are technically able and pedagogically committed to individualizing instruction, CSI Science can be a valuable addition to the science curriculum. Perhaps the most formidable deterrent to successful implementation is the teacher, who for many students is in a position so influential that student preference

often mirrors his mentor's preference. Those teachers who instruct CSI Science sections undergo a transition during which they self-evaluate their course(s), a very positive aspect, initially. Teachers of CSI Science who manage to emerge from transition with a negative attitude toward computing (problem solving), and are more-or-less forced to "use" the terminal, will be miserable failures and will have a detrimental influence on many of their students. An interesting sidelight, however, is the fact that some students--intuitively--are attracted to use of the terminal, and considerable pressure is exerted by these students on teachers who do not incorporate CSI actively.

Transfer of problem-solving techniques learned in CSI Science sections to subjects not actively involved should be anticipated. Many seniors enrolled in physics were also enrolled in "Nuclear Science," a non-CSI offering, and on their own used PS. Erstwhile users are quick to see new applications. Repeated on-site observations consistently yielded evidence of this transfer.

Students can be classified in terms of the probability that they would select CSI for a subsequent science course. Marginal evidence for supposing students actually "learned more," "understood principles," etc., better was witnessed. Refinement of classification is a problem for further research investigation, as is the issue of identifying the specific conceptual areas where CSI makes unique achievement gains plausible. Extensive, controlled experiments will be the vehicles from which answers to these questions will emerge.

FOOTNOTES

[a] See Klopfer, Leopold E., and Weber, Victor L., Jr. Individually Prescribed Instruction in Science. Pittsburgh: Learning Research and Development Center, University of Pittsburgh, March 1969.

[b] For example, see Kieren, Thomas E. Computer Assisted Mathematics Program (CAMP) Intermediate Mathematics, Teacher's Commentary. Glenview, Illinois: Scott, Foresman and Co., 1970. Especially, read the "Philosophy of CAMP" on page one, where CAMP project members point out that "...the problem-solving potential of the computer is readily extended to other curricular areas, notably science ..." It is interesting to note the first consideration used to guide CAMP materials development: "The computer must serve as a tool to help implement the central task: the learning of skills, concepts, and problem solving in mathematics." CSI Science is founded on this consideration. Also, see Dorn, William S., and Greenberg, Herbert J. Mathematics and Computing: with FORTRAN Programming. New York: John Wiley and Sons, 1967.

[c] The author would like to take this opportunity to express publicly his gratitude to Dr. Robert N. Haven, Director, Project LOCAL, and to Dr. Ludwig Braun, Director, Huntington Computer Project, for their kind and ready permission to reprint materials from their respective projects. These materials with their appropriate citations will appear in a compendium of computer routines to be published for limited use by the author's institution. Dr. Charles M. Hill, Superintendent of the Altoona (Pa.) Area Schools authorized reprinting of certain instructional materials also included in the compendium. Many varied computer applications in the sciences at the secondary school level are available from this source.

[d] Mr. Howard G. Newson, Superintendent, Titusville (Pa.) Area Schools, in a letter to the author. Mr. Newson's total commitment to the CSI Science project--from budgeting through follow-up activities--made possible our understanding of how to implement better CS I Science programs. Many students in this district have benefited educationally and socially directly as a result of Mr. Newson's continual drive to individualize instruction. It should be pointed out that Mr. Newson directed the underwriting of expenses--totally--to his school board, and that this type of commitment is indicative of a teaching-learning atmosphere where truly beneficial experimental treatments may be identified.

[e] Extended BASIC was presented by Mr. Dennis Namey, Assistant Director for Computing Activities, Central Susquehanna Intermediate Unit #16, Lewisburg, Pa.

[f] The present author, and Dr's Paul E. Bell and Michael Szabo, Science Education Department, The Pennsylvania State University.

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